PSZ 19:16 (Pind. 1/07)

UNIVERSITI TEKNOLOGI MALAYSIA

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name : **MUHAMAD RIDWAN B CHE AWANG**

Date of birth : **08 NOVEMBER 2012**

Title : **AUTONOMOUS BATTERY REPLACING MOBILE ROBOT**

Academic Session : **2011/2012**

I declare that this thesis is classified as :

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
√	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that Universiti Teknologi Malaysia reserves the right as follows:

1. The thesis is the property of Universiti Teknologi Malaysia.
2. The Library of Universiti Teknologi Malaysia has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

SIGNATURE | **SIGNATURE OF SUPERVISOR**

891108-03-5953
(NEW IC NO. / PASSPORT NO.)

DR. AHMAD 'ATHIF B MOHD FAUDZI
NAME OF SUPERVISOR

Date : 3 JULY 2012

Date : 3 JULY 2012

NOTES : * If the thesis is CONFIDENTAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of the degree of Bachelor of Engineering (Electric - Mechatronics)"

Signature	: ....
Name	: DR. AHMAD 'ATHIF B MOHD FAUDZI
Date	: 3 JULY 2012

AUTONOMOUS BATTERY REPLACING MOBILE ROBOT

MUHAMAD RIDWAN BIN CHE AWANG

A report submitted in partial fulfillment of the
requirement for the award of the degree of
Bachelor of Electrical Engineering (Electric – Mechatronics)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JULY 2012

I declare that this thesis entitled "*Autonomous Battery Replacing Mobile Robot*" is the result of my own research except as cited in the references. The thesis has not been accept for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : MUHAMAD RIDWAN B CHE AWANG

Date : 3 JULY 2012

Dedicated with full of love to my beloved mother, father and family.

ACKNOWLEDGEMENTS

In the name of ALLAH, the Most Gracious and the Most Merciful.

First and foremost, I would like to thank to Allah for giving me a chance and always guiding me in completing this thesis. During the process, make me realize bit by bit about what the mechatronics is. It requires a lot of patience and contribution with all sort of problems but Alhamdulillah, Allah is always show me on the way, Alhamdulillah.

My special thanks also go to my project's supervisor, Dr. Ahmad Athif bin Mohd Faudzi for the help and the guidance throughout the process. Also, thanks to all student supervised by him, for lending me a hand when I need.

Then, I would like to express my highest appreciation to my beloved parents for their support which is always made me strong to face all the obstacles and encourage me to walk along my path.

Last but not list, thanks to Mechatronic Intelligent Design for providing me a space to work, also for lending me their hand during my work and thanks to all who are involved and help me in doing this thesis. Thanks you very much.

ABSTRACT

This project presents the design and development of a mobile robot for pallet lifting with auto-recharge function. A special dock as the battery charger station is designed to power the robots battery. The concept of this project is to make the mobile robot to perform its task (carrying pallet) continuously without human intervention for recharging its battery. When the robot is in low power condition, it will automatically go to the charger dock and exchange its battery. Two Sealed Lead Acid (SLA) 12V battery will be used to power up the robot and MAX8211 chip is used to monitor the voltage. Signal will be sent to the controller when the voltage drops to a minimum level. The robot will detect the location of charger dock by analyzing infrared beam transmitted by the charger dock which can reach up to 10meters far. A mechanism for battery auto-change is designed at the docking area to replace the empty battery at the robot. This project can be used for transferring goods (pallet lifting) from one station to another station when the task needs to be done repetitively and continuously.

ABSTRAK

Projek ini membentangkan rekabentuk dan pembangunan robot mudah alih untuk mengangkat palet dengan fungsi pengalir masuk automatik. Satu dok khas sebagai stesen pengecas bateri direka untuk mengecas bateri robot. Konsep projek ini adalah untuk membina satu robot mudah alih yang menjalankan tugasnya (iaitu membawa palet) berterusan tanpa campur tangan manusia untuk mngecas semula baterinya. Apabila robot itu berada dalam keadaan kuasa rendah, secara automatik ia akan pergi ke dok pengecas dan menukar baterinya. Dua biji Bateri Asid Utama Terkedap (SLA) bervoltan 12V akan digunakan untuk menjalankan fungsi robot dan cip pembanding voltan quad dengan tambahan litar khas digunakan untuk mengukur voltan bateri. Isyarat akan dihantar kepada pengawal apabila voltan bateri capai ke tahap yang minimum. Robot akan mengesan lokasi dok pengecas berdasarkan pancaran inframerah yang dipancarkan oleh dok pngecas yang boleh mencapai jarak sehingga 10 meter. Satu mekanisme berfungsi sebagai penukar automatik direka pada dok pengecas bateri untuk menggantikan bateri yang bervoltan rendah di robot. Projek ini boleh digunakan untuk memindahkan barangan (mengangkat palet) dari satu stesen ke stesen yang lain apabila tugas tersebut perlu dilakukan berulangkali dan berterusan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS / ABBREVIATIONS

AC	-	Alternating Current
AGV	-	Autonomous Guided Vehicle
CAD	-	Computer Aided Design
DC	-	Direct Current
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
IC	-	Integrated Circuit
ID	-	Identification
IDE	-	Integrated Development Environment
IR	-	Infrared
LED	-	Light Emitted Diode
PIC	-	Peripheral Interface Controller
RAM	-	Random-Access Memory
RC	-	Radio Control
RF	-	Radio Frequency
RFID	-	Radio Frequency Identification
rpm	-	revolution per minutes
SLA	-	Seal Lead Acid
USB	-	Universal Serial Bus

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Autonomous mobile robots are built based on the application and human need, for example to explore a new area or planet, to detect mines in an area and to transfer goods from a point to another point. Each application needs the robot to still alive until all of the tasks is done. Yet, most of these autonomous mobile robots have limited operation time due to their power supplies and impossible to complete its task especially if the application does a task repeatedly in long term.

The purpose of development in autonomous mobile robot is to eliminate human intervention in most application. But, the limited time operation still need human interferes to recharge its batteries. This result in a non-continuous robot task cycle as illustrated in Figure 1.1(a) and the main objective to eliminate human work still not achieved. An addition research needs to be constructed to overcome this problem.

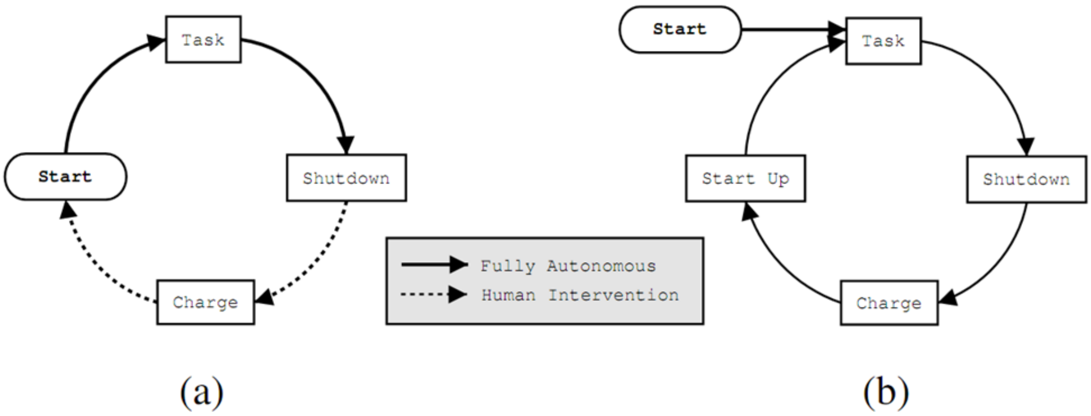


Figure 1.1 Robot task cycle (a) with human intervention (b) without human intervention.

1.2 Problem Statement

In an electronic factory, all components of a circuit module will be assembled in a circuit board phase by phase. The circuit board is placed on a pallet and will be passed from a checkpoint to another checkpoint using an automatic conveyor. The pallet acts as platform for circuit module while it is on the conveyor. After the last checkpoint, the complete circuit module will be packing in a box and ready to supply while the empty pallet will be collected and transfer back to first checkpoint for another circuit module. Usually the pallet is transferred by a human operator in dozens.

In Celestica Electronic (M) Sdn Bhd factory, they have their own autonomous mobile robot to transfer the empty pallet back to first checkpoint named Hitachi CFT – A.G.V. This autonomous guided vehicle (AGV) is not full automatic as it needs human to load the pallets on it and the human also need to push run button to move this mobile robot.

Figure 1.2 Hitachi CFT – A.G.V

Moreover, the mobile robot is powered by rechargeable batteries which have limited time operation and need to be charged each time the batteries in low power state. Basically, batteries need about 2 to 3 hour to fully charge. While the batteries are charging, the transfer of pallet task needs to be done by human operator.

1.3 Objectives

Based on the problems had been discussed above, this project is conducted. The objectives of this project are:

1) To build a continuous operating mobile robot without human intervention.
2) To construct a mobile robot installed with auto conveyor.
3) To build an automatic battery replacing system

1.4 Scope of the Project

In order to make sure the results of this project are achieved, there are four scopes had been outline and need to be constructed; mechanical, electronics, software and field area.

1.4.1 Mechanicals

This project needs three assembly of mechanisms; mobile robot, charger dock and battery box.

1) The mobile robot is two wheeled drive mechanism, powered by two Seal Lead Acid 12V batteries. Four infrared receiver sensors are attached to the mobile robot and their function is to detect the location of charger dock.

2) Charger dock, which is function as battery charger is the main part of this project. On top of it will have a battery replacer mechanism and surround by infrared transmitters to transmit infrared beam.

3) Battery box consist of two SLA 12V batteries. The box can be attached and detached from its socket.

1.4.2 Electronics

Six circuit boards are used in this project. There are 2 main boards for mobile robot and charger dock, battery charger circuit, long range infrared transmitter circuit, battery voltage monitor circuit and UIC00B – USB PIC Programmer to load program to microcontroller. Both main boards are using microcontroller dsPIC30F4011 as the controller.

1.4.3 Softwares

The programming code is compiled using MPLab C Compiler and then the hex file format will be loaded to the microcontroller using PICkit 2 software.

1.4.4 Field area

This project needs a 3.5 m x 6.5 m filed area to run. It is designed to illustrate the situation in electronics' factory. The area is illustrated in Figure 1.3 below. It will have two station; Station 1 and Station 2. Station 1 will be end point of the conveyor, while Station 2 is the start point of the conveyor. So, mobile robot will transfer empty pallet from Station 1 to Station 2. The charger dock will be placed in center in between of Station 1 and Station 2. This design will make sure the mobile robot will receive infrared beam while it is in line.

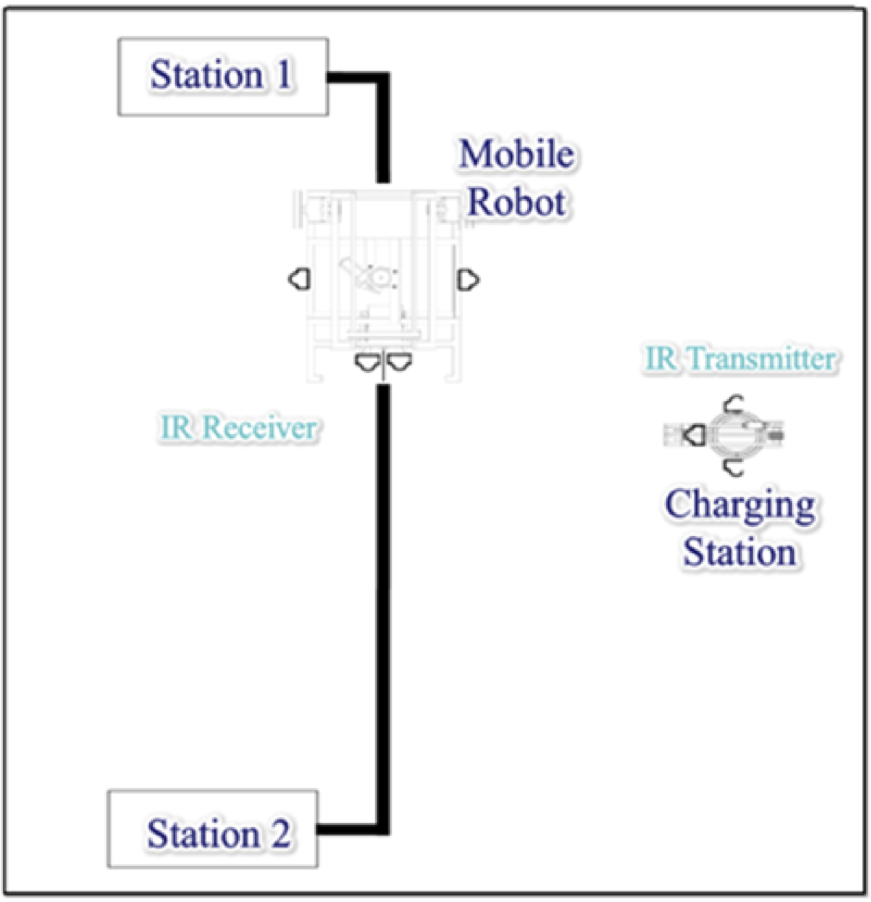


Figure 1.3 Field area for the project

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Introduction

Until now, many researches had been done on autonomous recharging mobile robot. The important issues that need to be considered while design an autonomous recharging mobile robot are the method for mobile robot to locate its dock place and circuit to monitor battery voltage.

2.2 Locating the Dock Place

Locating is similar to the tracking technologies which is both of them used to know where are the location of particular things. According to O. Diegel, J. Potgieter, and T. Cao (2005), in their paper, "Where's Waldo? Low Cost RF Indoor Tracking System", some of the commonly available technologies that are suitable for tracking networks include; infrared, radio frequency identification (RFID), Direct Current (DC) electromagnetic and ultrasound. In addition, vision technique also one

of the most popular method and widely used for autonomous docking system. Each of them has its own advantage and disadvantage.

2.2.1 Infrared as Location Detection

The benefits of using infrared are it's consumes low power, low in cost and compact in size. But infrared is limited by interference of ambient light and can be disturb by other infrared devices. It is also bounded by line of range limitations. For locating dock place, this method can be implementing by installing infrared transmitter to the dock place while the passive infrared receiver can be attached at the mobile robot. The mobile robot will acknowledge the dock location when the passive IR receiver detected IR beam and after roaming around.

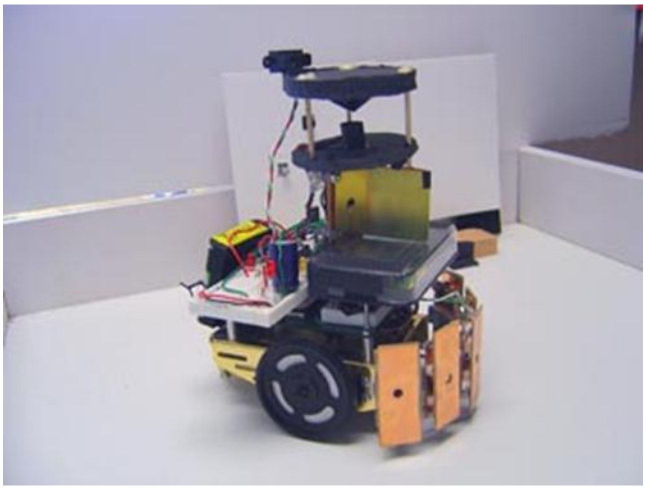
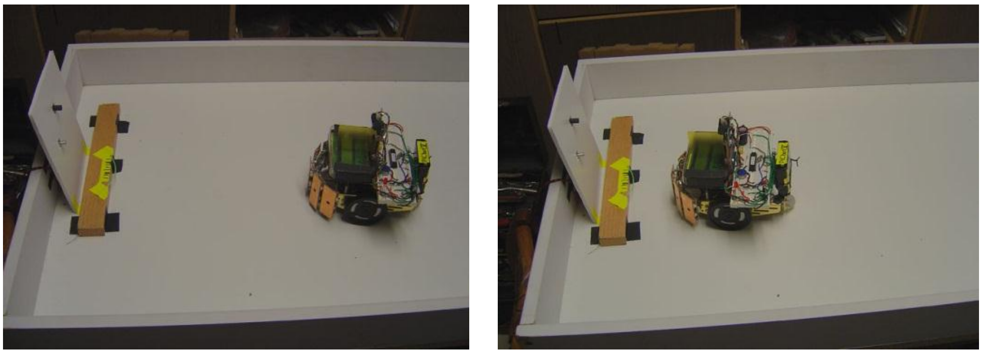


Figure 2.1 PICbot V

The best example of implementation of this method is the research conducted by Chris and Dawn Schurs' (2007) titled by "Docking Logic – Autonomously Finding the Charging Base and Recharging". Using small robot named PICbot V; they implement infrared beam method to locate the dock place. Panasonic infrared

receiver (PNA4602) was attached to the robot to detect 38 kHz infrared beam transmitted from the dock. A modification was made to the IR transmitter at the dock, so that it can transmit IR beam in a long range. For their project, they limit the IR beam to 10 ft. to make sure the signal is stable.

The weakness of this system, when it acknowledges the batteries is low, it will move around until it detects the IR beam. What will happen if the batteries are totally out of power before the mobile robot detects the IR beam?



(a) (b)

Figure 2.2 Process of locating dock place (a) PICbot V moving around until detect IR beam (b) then move forward to the dock.

2.2.2 Radio Frequency Identification Tag and Location Proximity

Differ with infrared; RF can pass through common material which is not limit to line of sight range. Also, its range can reach till 30m compare to infrared which its typical range is only about 5 m. RFID is a system which uses either passive radio tags or active for the identification. The transmitter (called as the reader) will transmits a low-power radio signal. The tag with specific identification (ID) receives

the signal and power up the integrated circuit (IC) on it. Then briefly, the IC will converse with the transmitter for verification and exchanging data.

(a) (b)

Figure 2.3 RFID Devices (a) RFID Passives Tag (b) RFID Reader

The distance of the tag can be approximately assumed by calculating its speed propagation and time responses while the process of transmit and receive data. O. Diegel, J. Potgieter, and T. Cao (2005), in the same paper, used same method in locating its mobile robot.

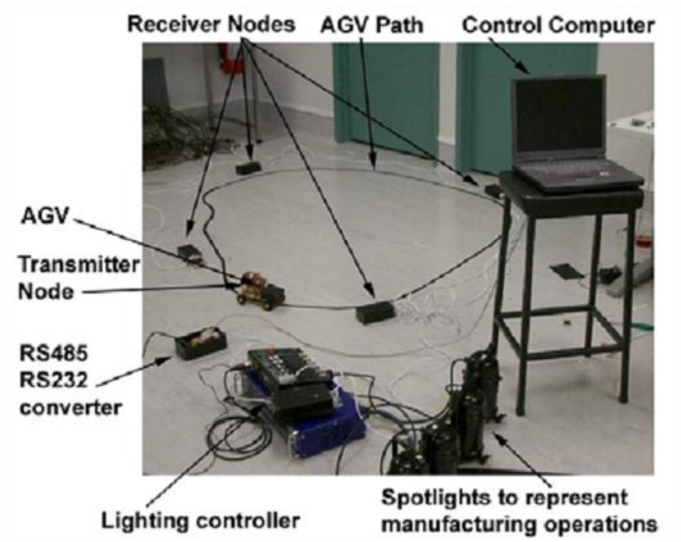


Figure 2.4 Tracking system setup using RFID technologies

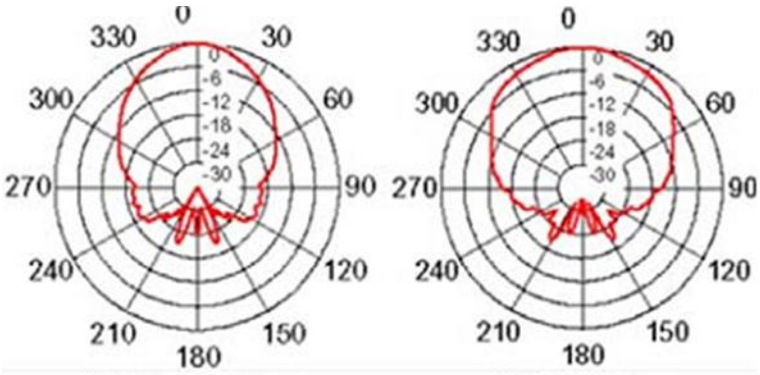
While the mobile robot followed the path, the RFID tag on it was detected by the reader at the receiver nodes and the nearest receiver nodes will sent data to the controlling computer using RS485 network. The controlling computer will acknowledge the ID of the reader module as well as the distance between the robot and the reader. Note that the coordinate of the reader is fixed.

2.2.3 DC Electromagnetic

Besides, in high positioning systems, DC electromagnetic is commonly used. Its signals are very sensitive to surrounding interference, even a metal can give a signal if it in its area. As a result, high level filter is needed and the calibration needs to be done precisely for the best output. Although its signal propagation is high, its range limited to only 1 m to 3 m.

2.2.4 Low Cost Ultrasound

The last one is ultrasound, which is become more widely used in positioning system. Its propagation speed is fixed to 343 m/s; make the length measurement become more precise. Based on research conducted by L. Dazhai, F Hualei and W. Wei (2008), titled by “Ultrasonic Based Autonomous Docking on Plane for Mobile Robot”, the intensity of ultrasonic is influenced by the angles of the transmitter and receiver.



(a) (b)

Figure 2.5 Intensity character of Ultrasonic Sensor (a) Transmitter (b) Receiver

Small angle between transmitter and receiver gives high intensity. They used this character of ultrasound as localization technique. Based on the characteristic the angle between transmitter and receiver can be calculated using trigonometric equation.

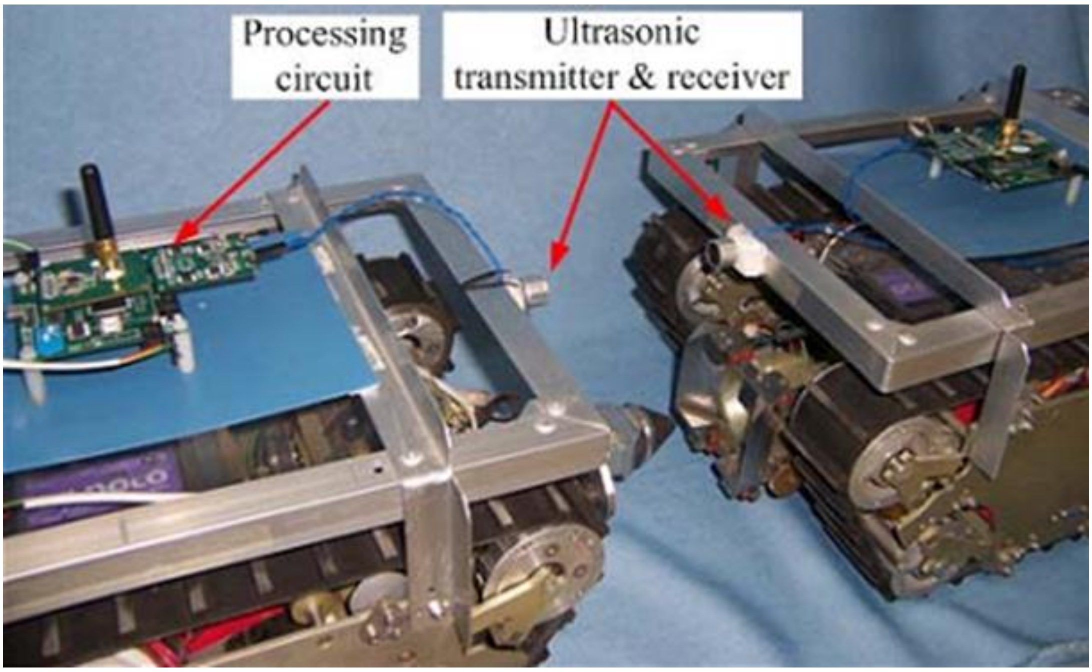


Figure 2.6 Position of Transmitter and Receiver Set

2.2.5 Vision Method for Localization System

Vision technology nowadays are widely use at autonomous robot. By interfacing the robot with the computer, the visual of environment of a robot can be clearly monitored. As this method camera as its sensor, it is bounded with line of sight limitation and it is limited to angle of the camera can view. Also, the robot cannot get full review if there object obstruct its sight. But still we can adjust the height of the camera to a little bit higher to get a better view.

An experiment, titled by “Visual Homing: Experimental Results on an Autonomous Robot”, developed by P. Arena *et al.* (2007) apply visual system as the main method to locate the position of the docking place. The camera was added with spherical mirror (eye fish) to get 360^0 view.

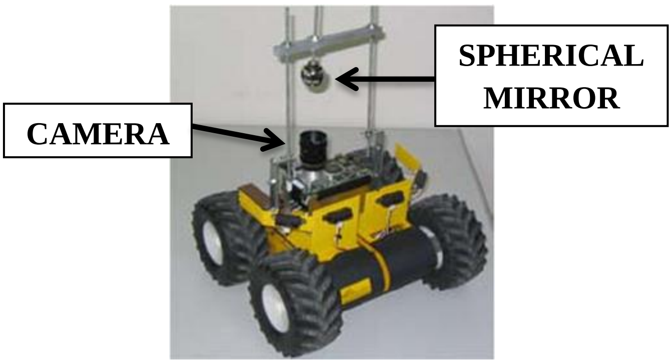
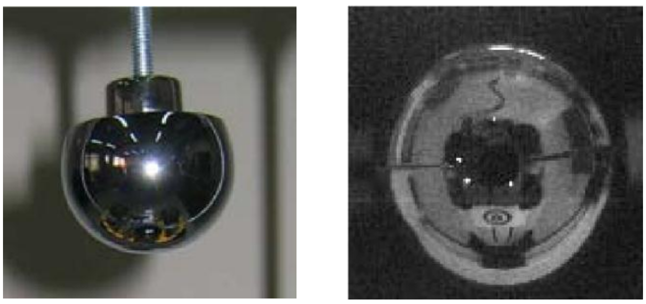


Figure 2.7 Position of camera and the spherical mirror



(a) (b)

Figure 2.8 Spherical mirror (a) side view (b) bottom view (camera view)

2.2.6 Range Light Vision

Another research on autonomous docking and recharging technology is “Docking and Charging System for Autonomous Mobile Robots”. This research was developed in University of Brescia by C. Riccardo *et al.* (2005). They use range of different color of light source to determine the angel of the dock. Figure 2.9 illustrated the concept of determine the direction of the dock using range light method.

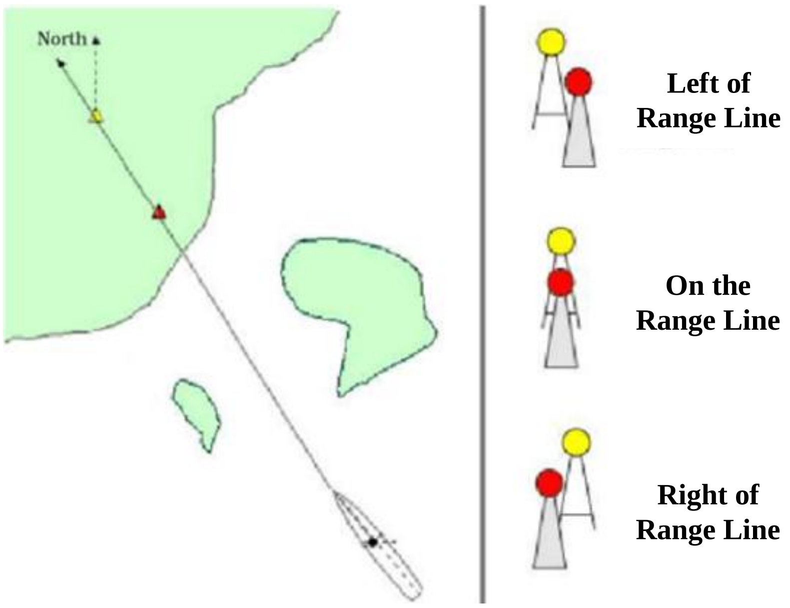


Figure 2.9 Locating dock place by range light concept

2.3 Battery Voltage Monitor

Battery voltage monitor also be the most important systems in designing autonomous recharging mobile robot. The microcontroller needs to acknowledge when the batteries is in low state so that it have enough power to make a path to dock

place. If the microcontroller did not get the signal of low battery power, the autonomous recharge system cannot be preceded.

2.3.1 Using Quad Voltage Comparator

In a research conducted by E. Maningat *et al.* which is titled by “Random Walk Application for Autonomous Vacuum Cleaner Robot”, they used quad voltage comparator as a monitor to the voltage of 12V lead acid battery. Using 4 Light Emitted Diodes (LED); which is each of them as indicator of 25% change in charge condition of the battery. The battery is considered as fully charge if all of 4 LEDs are light on.

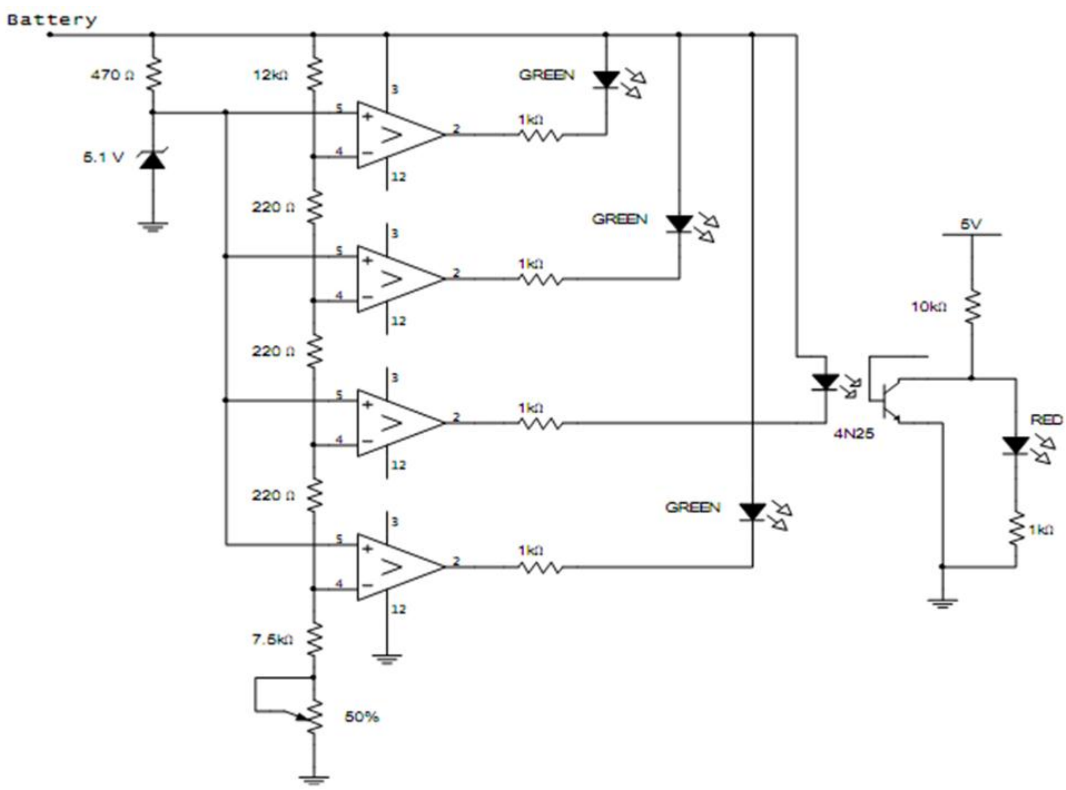


Figure 2.10 Circuit diagram for 12v lead acid battery meter

2.3.2 LED Dot/Bar Display Using Chip LM3914

The heart of this circuit is IC LM3914, product of National Semiconductors. The LM3914 can monitor voltage of a voltage supply then give output to LEDs in dot or bar mode. This IC can support supply voltage in range of 3V to 25V, while the intensity of LED's brightness can be controlled using an external resistor. Refer to Figure 2.11, resistor R4 is used to control the brightness of LEDs while resistor R1 and variable resistor R2 are used as voltage divider which is the variable resistor R2 can be tuned to set the minimum battery level.

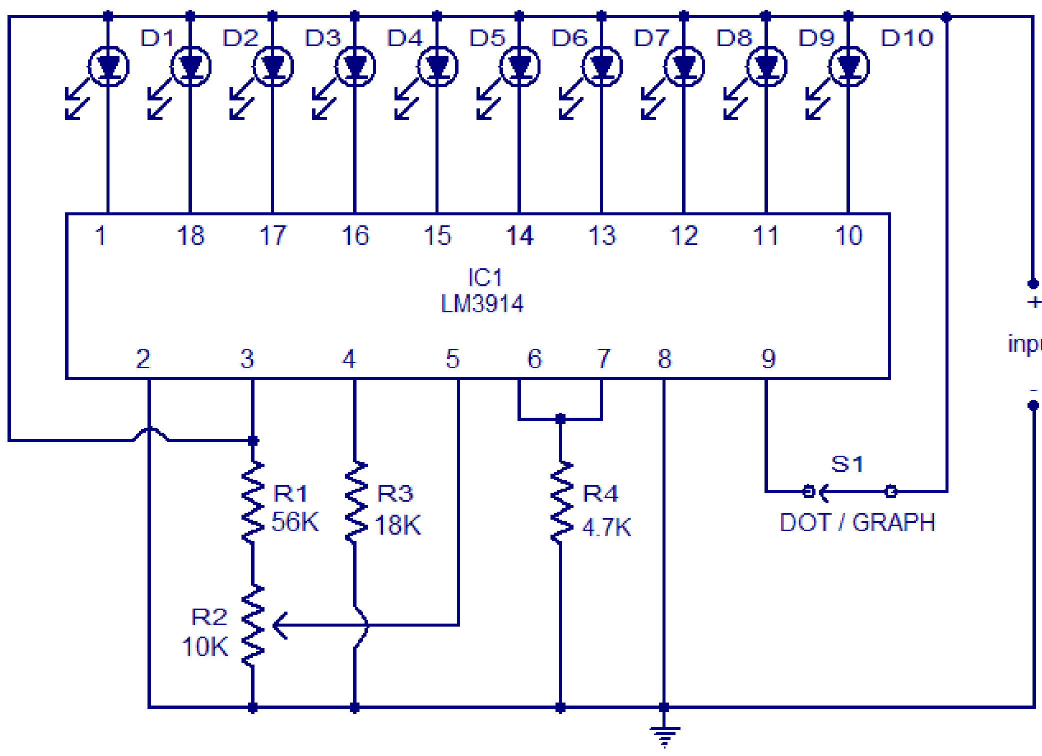


Figure 2.11 Battery monitor circuit using LM3914

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, to conduct a project, it required a systematic planning to make the flow of the project is in control and the output result is as expected. This chapter discusses the flow of this project and how this project will be conducted. This can be the guideline in conducting this project. Basically this project is divided into 3 major part; mechanism, electronic and programming. The flow can be illustrated as in Figure 3.1.

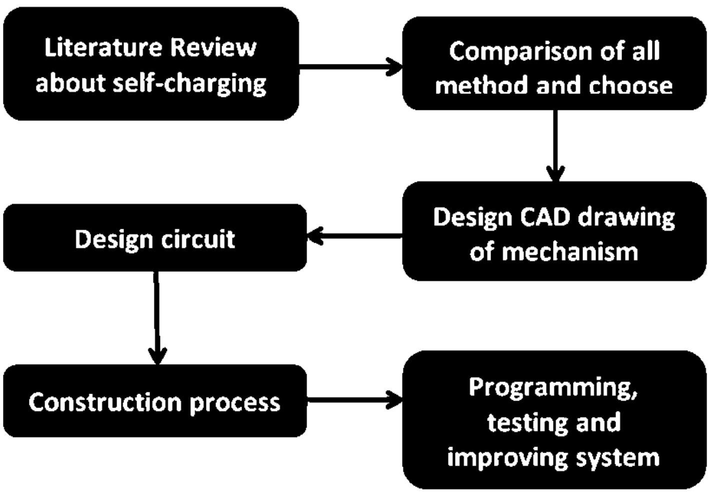


Figure 3.1 Flow of constructing this project

3.2 Overview of Overall System

This project consists of two parts; mobile robot and the dock place. The overall system of these two parts can be divided into 5 main systems. The dock place will be installed with 2 systems; charging system and battery replacer system, while at the mobile robot will has 3 systems; locating the dock place, battery voltage monitor system and line following.

First point of the mobile robot is at Station 2 (refer Figure 1.3) or the end of the conveyor system. The mobile robot will wait there until its infrared sensor detects the presence of empty pallet. Then it will do line following to the Station 1 (refer Figure 1.3) to unload empty pallet to Station 1 (start point of conveyor system). After done unloading, the mobile robot will return to Station 1 and again, wait for the presence of empty pallet, then load it to transfer to Station 1. The mobile robot will do the task continuously until its battery reaches to minimum voltage level.

When the batteries are in low power, the battery voltage monitor will send a signal to microcontroller and the microcontroller will save the current task. The signal from passive infrared receiver (locate at the base of the mobile) will be processed and the microcontroller will made decision whether turn right or left until the robot is facing to the dock place perpendicularly. After that, the robot will moves forward until reach the dock place and touch the limit switch installed at the charger dock.

At the charger dock, after receive signal from the limit switch, battery replacer mechanism will align its arm so it is in line with battery box in mobile robot. Then, it will clip and pull the battery box to go and load the battery box to the charging station. After that, full charge battery (which is spare battery already store

on the storage station of charger dock) will be loaded to the mobile robot. The mobile robot, afterwards, will return to its previous location to continue its task.

3.3 Mechanism Part

Mechanism in field of engineering can be defined as a system or structure of moving parts that performs some function, especially in a machine. In other word, mechanism in combination of joining that can perform a function. Mechanism need actuator to make it moves in and sensor is used to give feedback on its movement. This actuator and sensor allow user to control each movement of mechanism in desired value by programming. Both mobile robot and charger dock have their own design of mechanism and actuator.

3.3.1 Mobile Robot

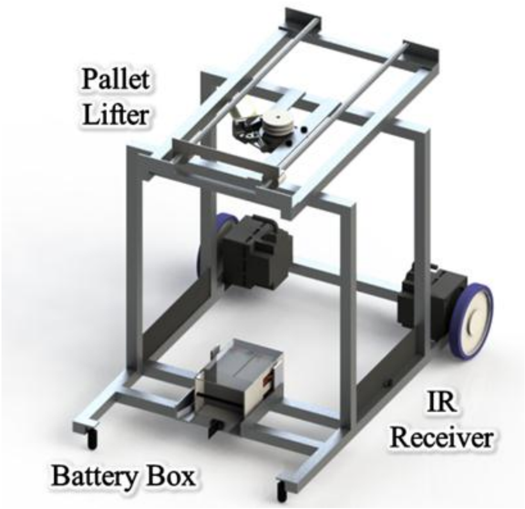


Figure 3.2 Mobile robot's CAD design

Figure 3.2 illustrate the drawing for the mobile robot. On top of the robot is the auto conveyor part which is functioning as a platform to store the empty pallet while the robot in transferring process. A DC motor is used as actuator to load empty pallet into the auto conveyor. At the base part, a pair of DC motor is used to navigate the robot while four passive infrared sensors are placed at the base of the mobile robot.

The function of these IR sensors is to detect IR beam that has been transmitted by the charger dock. As only IR sensor at right and front-right detect the IR beam, the mobile will acknowledge the charger dock now is in its right hand side. It will automatically turn to the right until both of front IR sensors detect the IR beam. The function of the divider between both of front IR sensors is to make sure the mobile robot is perpendicular to the charger dock.

3.3.2 Dock Place

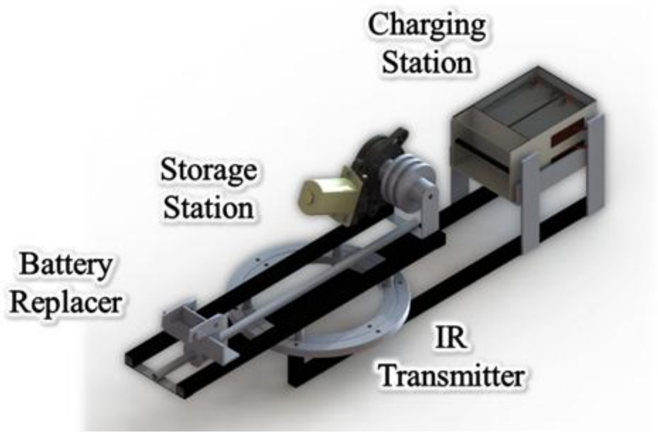


Figure 3.3 Charger dock's CAD design

Figure 3.3 is the rough design for dock place. As the mobile robot comes from any direction in range of 0 to 180^0, the charger dock need to be design with rotating mechanism so that it can still replace the battery even the robot comes from any angle. The dock place also installed with slider so that it still can reach the batteries at the mobile robot.

Charger dock consists of 4 parts; charging station, storage station, battery replacer and IR beam transmitter. Charging station is used as station to charge low power battery. There will be a socket for battery box and this socket is design to make the battery replacing process become easier. Second part of this charger dock is storage station. A full charge battery will be stored at this station until the mobile robot come with the low power battery.

The main part of charger dock is battery replacer mechanism. It can move in two degrees of freedom; rotating and sliding. End tool for battery replacer is locking trigger which is function to lock the battery while in transferring process. The rotating feature allows this mechanism to align its slider in line with the battery box socket at mobile robot and charging station.

3.3.3 Battery Box

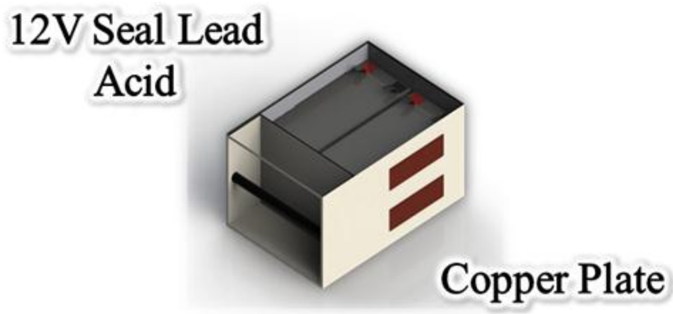
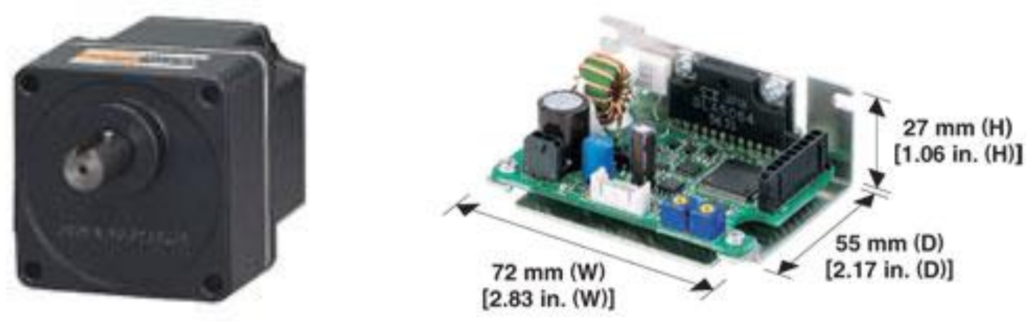


Figure 3.4 Battery box’s CAD design

Two SLA 12V batteries are placed together in a box, while each one of the batteries terminal will be connected to the copper plate at the side of the box. Negative terminal of each battery is connected to the each copper plate on the left side of the box while positive terminal of the each battery is connected to the each copper plate on the right side of box. The purpose of designing this battery box is to make replacing battery process easier.

3.3.4 Actuators

Each movement of mechanism in this project will be actuated using an actuator. Three types of actuators are used in this project; DC brushless motor, DC brush motor and RC servo motor. A pair of DC brushless motor, model BLH Series Brushless motor is used to drive the two wheeled mobile robot. This model is a dedicated high-strength gearhead for brushless motors that also supports high-speed rotation and a compact board-type driver is needed to drive BLH Series Brushless motor.



(a) (b)

Figure 3.5 (a) BLH series brushless motor (b) compact board-type driver

Table 3.1: Specification of BLH series brushless motor

Item	Specification
Motor Size	50W (1/15 HP)
Gear Ratio	5:1
Speed Range	20 – 600 rpm
Power Supply	24 VDC
Rated Torque	7.9 lb-in / 0.9 Nm

Besides DC brushless motor, DC brush motors are widely used in this project such as, DC geared motor, power window motor and DC motor. On mobile robot, power window motor is used to load and unload pallet while on charger dock, it is used to rotate the arm of battery replacer mechanism.

Figure 3.6 Power window motor

Table 3.2: Specification for Power Window Motor

Item	Specification
Voltage Rating	12 VDC
Speed (No Load)	85 rpm
Current (No Load)	3 A
Current (Load)	7 A
Current (Lock)	20 A
Torque	30 kg cm

Another DC brush motor that is used is DC geared motor, model SPG30-30. This motor is used for sliding part of battery replacer mechanism. This motor is suitable for light use such as bank note machine, handling machine and to drive light mobile robot.

Figure 3.7 SPG30-30 DC geared motor

Table 3.3: Specification for SPG30-30 DC Geared Motor

Item	**Specification**
Voltage Rating	12 VDC
Output Power	1.1 Watt
Rated Speed	103 rpm
Rated Current	410 mA
Rated Torque	127.4 mN m

Beside both DC geared motor and power window motor, RC servo motor also used to actuate locking trigger at the end tool of battery replacer mechanism. It is necessary for the actuator to move by angel of 90^0 to control each time of trigger. That is why RC servo motor is used to trigger the locking trigger.

Figure 3.8 RC servo motor

Table 3.4: Specification of RC servo motor

Item	Specification
Voltage Rating	6 VDC
Speed	0.12 s / 60^0
Torque	2.70 kg cm
Size	(29 x 11.7 x 30.2) mm
Weight	16 g

3.3.5 Sensors

Sensor is used to give a feedback of each movement done by the robot. This sensor will be connected to the microcontroller and be declared as input. In this project, there two sensor are used; limit switch and IR sensor. Limit switch is widely used in this project to limit the movement of mechanism. Once this limit switch has been pushed, signal will be sent to the microcontroller, and microcontroller will give stop signal to the actuator.

Figure 3.9 Limit switch

IR sensor can be used to detect the presence of an object. For example, in this project, IR sensor is used to detect the presence of empty pallet. Besides, this sensor can also use for line following system. Different colour of floor will reflect different intensity of light emitted by IR transmitter. This situation will varied the resistance value of IR receiver sensor when it receives light reflect by the floor.

IR sensor also used to detect IR beam transmit by the charger dock. Four IR sensors will be placed at the base of mobile robot.

Figure 3.10 IR sensor and transmitter

3.4 Electronics

As mentions in Chapter 2, there are six circuit boards are used in this whole project. Two of them, main board circuit for mobile robot and battery voltage monitor circuit, are used for the system at the mobile robot, while three circuits are used for operation in charger dock. The circuits are main board circuit, battery charger circuit and long range IR transmitter circuit.

Both of main board, for mobile robot and charger dock, use microcontroller from Microchip which is dsPIC30F4011. To program those to microcontroller, UIC00B – USB PIC Programmer circuit will be used. This programmer is suitable to program most of PIC family from Microchip.

3.4.1 Power Supply Unit

Power supply is like the soul for the robot. Without power supply, a robot cannot function. As the mobile robot need to move free, whole system in mobile robot will be powered by two units of Seal Lead Acid 12V battery. This SLA 12V battery can reach up to 14.46 V in full charge mode (first time used). The advantage of using SLA battery is it is low cost, robust and low maintenance required.

Figure 3.11 SLA 12V battery

In other hand, charger dock does not need to move freely as it needs to be placed fix at a place. So, it is not necessary to use battery to power its circuit. Charger dock use AC to DC adapter as it power supply, so it has no problem with limited time operation as mobile robot.

Figure 3.12 12 VDC AC to DC adapter

3.4.2 Main board Circuits

Main board circuit is the interfaces circuit for microcontroller that used to control all activities in the system. The design of the circuit is depended on how many inputs and outputs of the microcontroller and what are the inputs and outputs that been used. Microcontroller dsPIC30F4011 is used as the brain for the mainboard. This chip offers 27 I/O pins that can be used as input and outputs. Figure 3.13 shows the pin diagram of dsPIC30F4011.

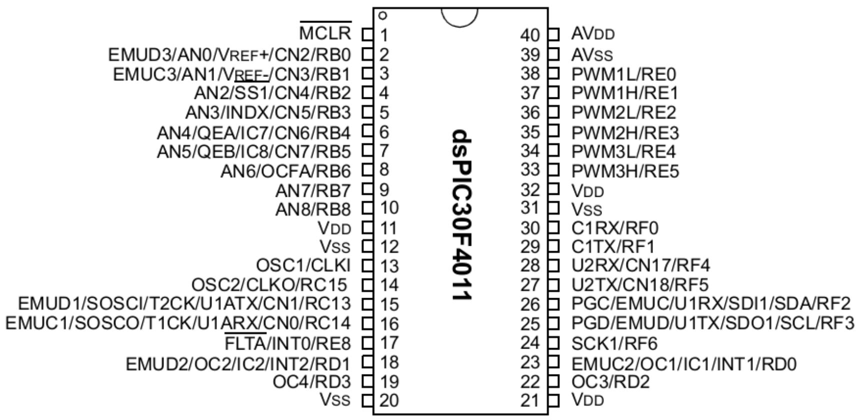


Figure 3.13 Pin diagram of dsPIC30F4011

The other specifications of this chip are:

1. 83 base instructions
2. 24-bit wide instructions, 16-bit wide data path
3. 48 kilobytes on-chip flash program space (16k instruction words)
4. 2 kilobytes of on-chip data RAM
5. 1 kilobyte of nonvolatile data EEPROM
6. 30 interrupt sources:

This microcontroller needs supply voltage of 5V to operate. For this reason, a 5V voltage regulator circuit is needed to regulate 12V voltage from battery to output of 5V. The main component to produce 5V of voltage is LM7805 chip (Figure 3.14). This chip can support input voltage in range of 7V to 28V. Figure below illustrated the circuit diagram for voltage regulator circuit.

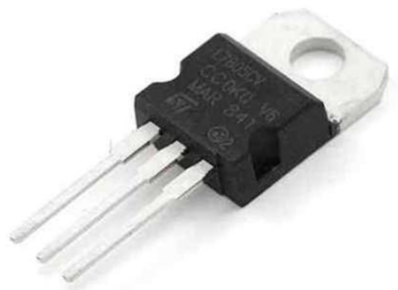


Figure 3.14 LM7805 chip

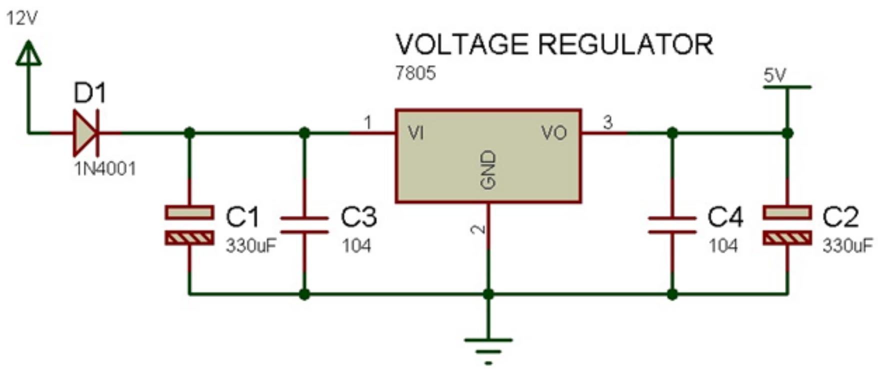


Figure 3.15 Voltage regulator circuit

With supply voltage of 5V, the basic circuit for microcontroller can be done. This basic circuit is needed to enable the microcontroller. Some pin need to be interface with other component to activate it function. Figure 3.16 below shows basic circuit for microcontroller to operate.

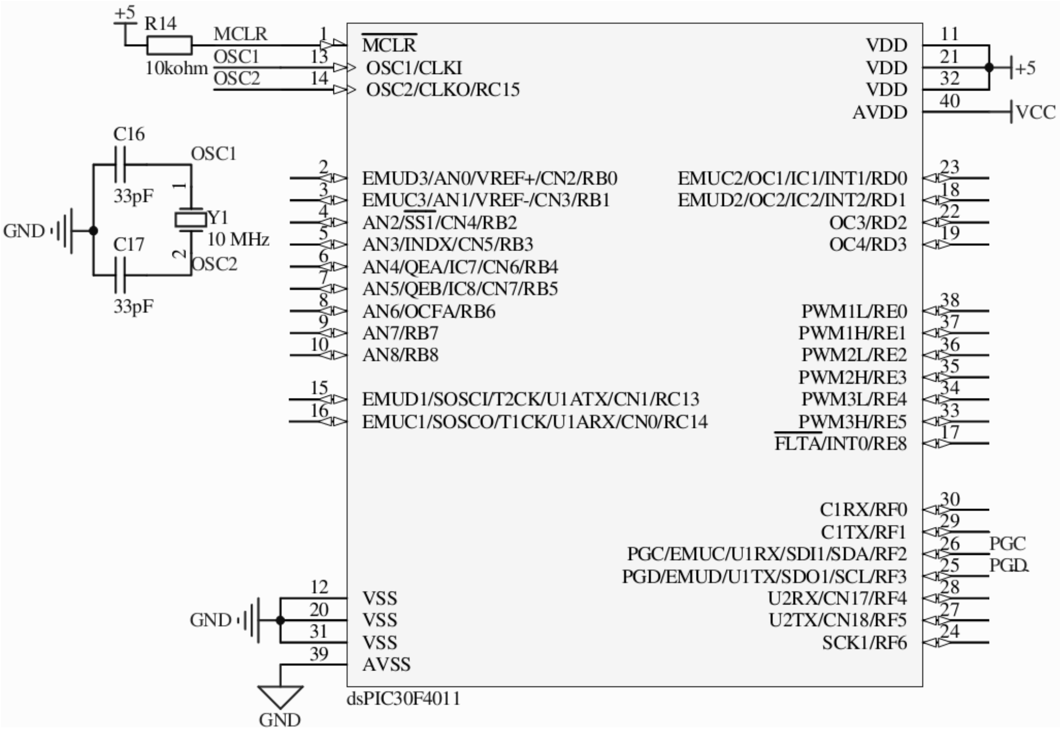


Figure 3.16 Basic circuit for dsPIC30F4011

Pin 1 is pin for reset purpose. A push button can be place to the pin if user needs to have a reset button. Pin 13 and 14 is connected to the oscillator which is function as clock for microcontroller. The value of oscillator can be varied depend on user needs as long as not more than 40 MHz but its capacitor's value need to be based on the oscillator value. For this project, this microcontroller use 10MHz of oscillator and 33pF of capacitor. The output of 5V from voltage regulator circuit will be connected to pin 11, 21, 32 and 40 while pin 12, 20, 31 and 39 will be connected to the ground. Lastly, pin for program purpose which is pin 25 and 26; connected to the UIC00B – PIC Programmer.

3.4.3 Battery Voltage Monitor

Battery voltage monitor is placed at the mobile robot to monitor current level of voltage. It is important to set the minimum voltage of the battery as to spare the power for the mobile robot to move to the charger dock. The minimum voltage is set to 12V. Main component for this circuit is LM324 chip (quad voltage comparator). This chip can support supply voltage range of 3V to 30V. Figure 3.17 shows the circuit diagram for battery voltage monitor circuit. LED4 will light on if the voltage reaches to 12V.

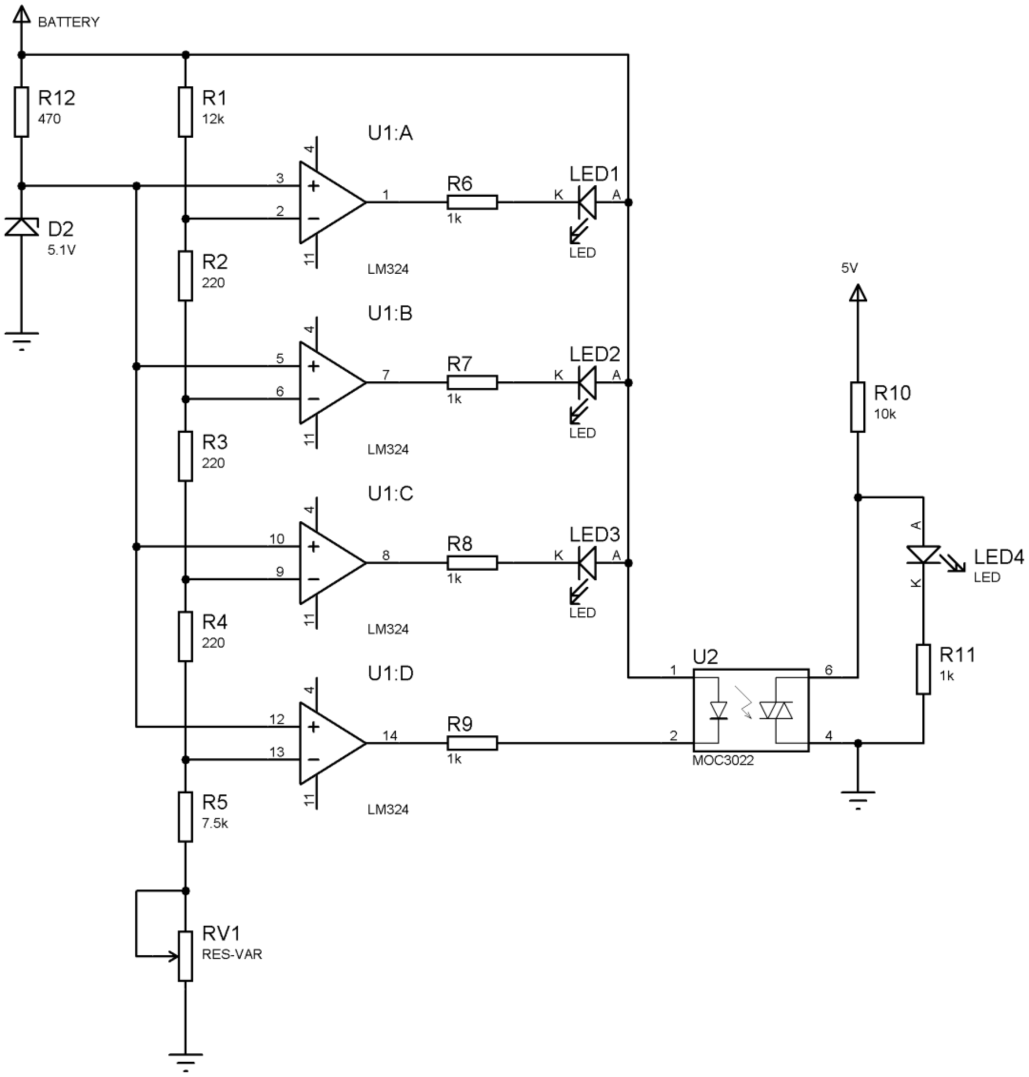


Figure 3.17 Battery voltage monitor circuit

3.4.4 Battery Charger Circuit

Battery charger circuit used to charge low power battery and will be placed at the charging station at charger dock. As the system is automatic system, the charger need to have auto cut-off charge system, which mean, the battery will stop charging if it is full charge and the circuit need to give a signal to the microcontroller to indicate that the battery is full charge. For the purpose, this project use auto cut-off battery charger by using LM338 as its heart. Its circuit diagram is illustrated as figure below.

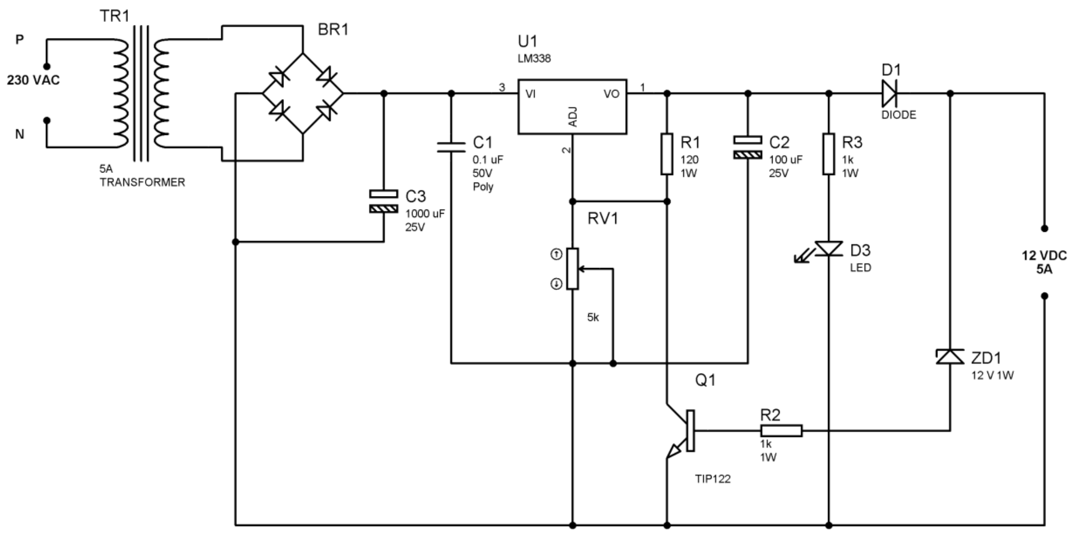


Figure 3.18 Auto cut-off battery charger circuit

3.5 Softwares

In constructing the whole project, there are several softwares that have been used. The used of these softwares can reduce the cost as we can stimulate what will happen with the design. In designing mechanism part, DS Solidworks 2010 software

is being used. DS Solidworks is a mechanical design which make easier in designing or sketching out ideas. Using easy understanding features, it is suitable for beginners of designer to try to learn using software in sketching.

Figure 3.19 DS Solidworks

MPLab IDE compiler is used to compile the programming code while PICkit 2 software is used when the compiled code need to be loaded to the microcontroller. When writing the programming code, it is advised to design flow chart of overall process. This flow chart will make programming part become easier. Figure 3.21, 3.22 and 3.23 illustrate flow chart of overall process for this project.

Figure 3.20 MPLab IDE C Compiler

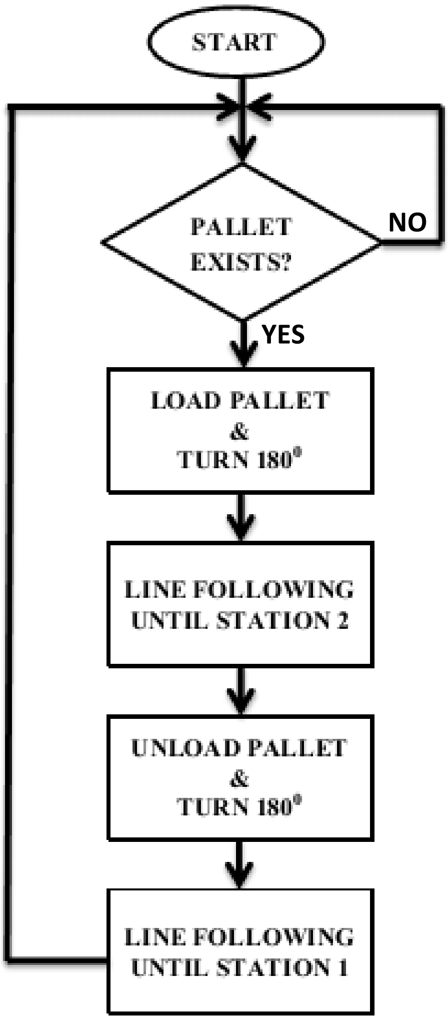


Figure 3.21 Normal process' flow of mobile robot

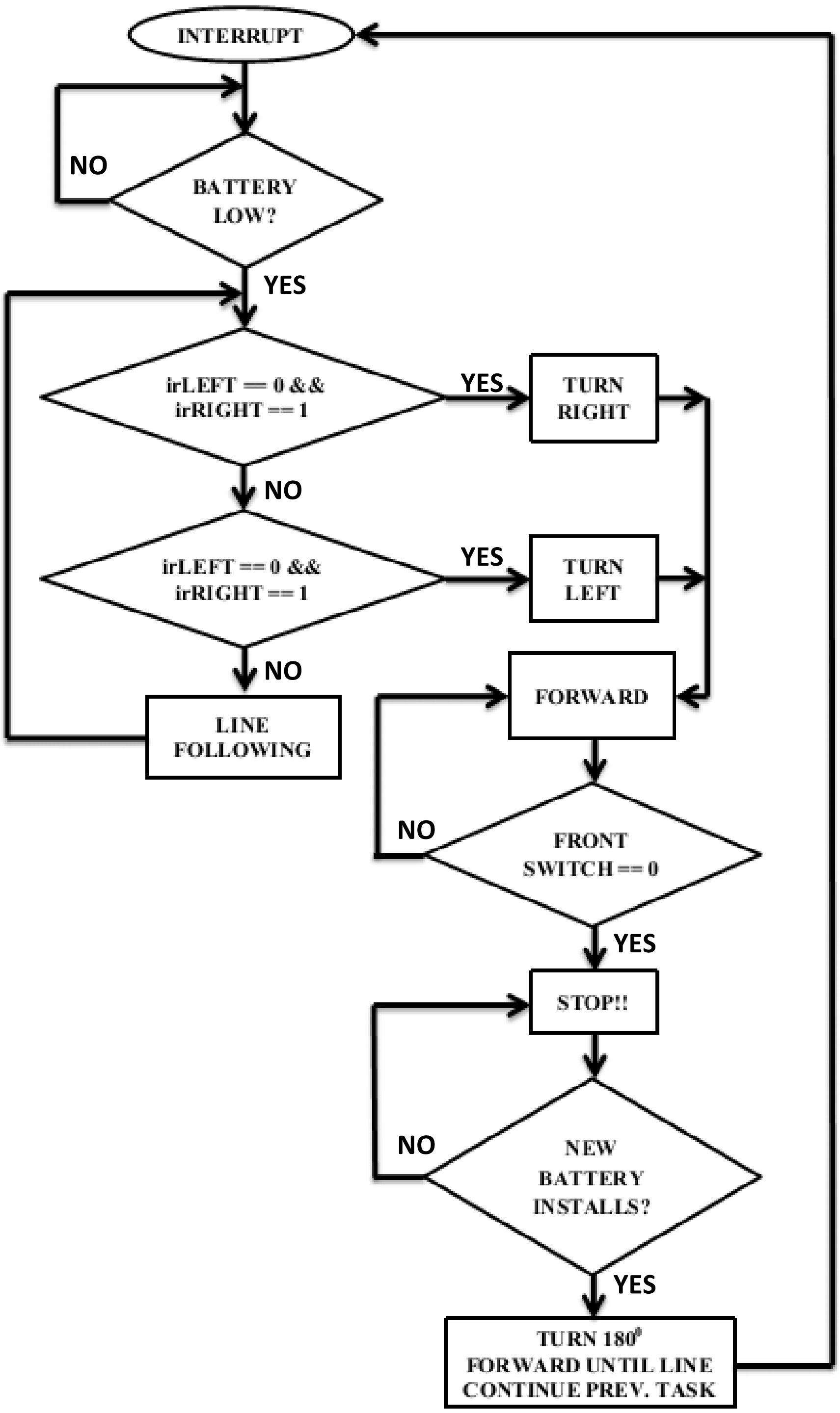


Figure 3.22 Process' flow of mobile robot in low power battery

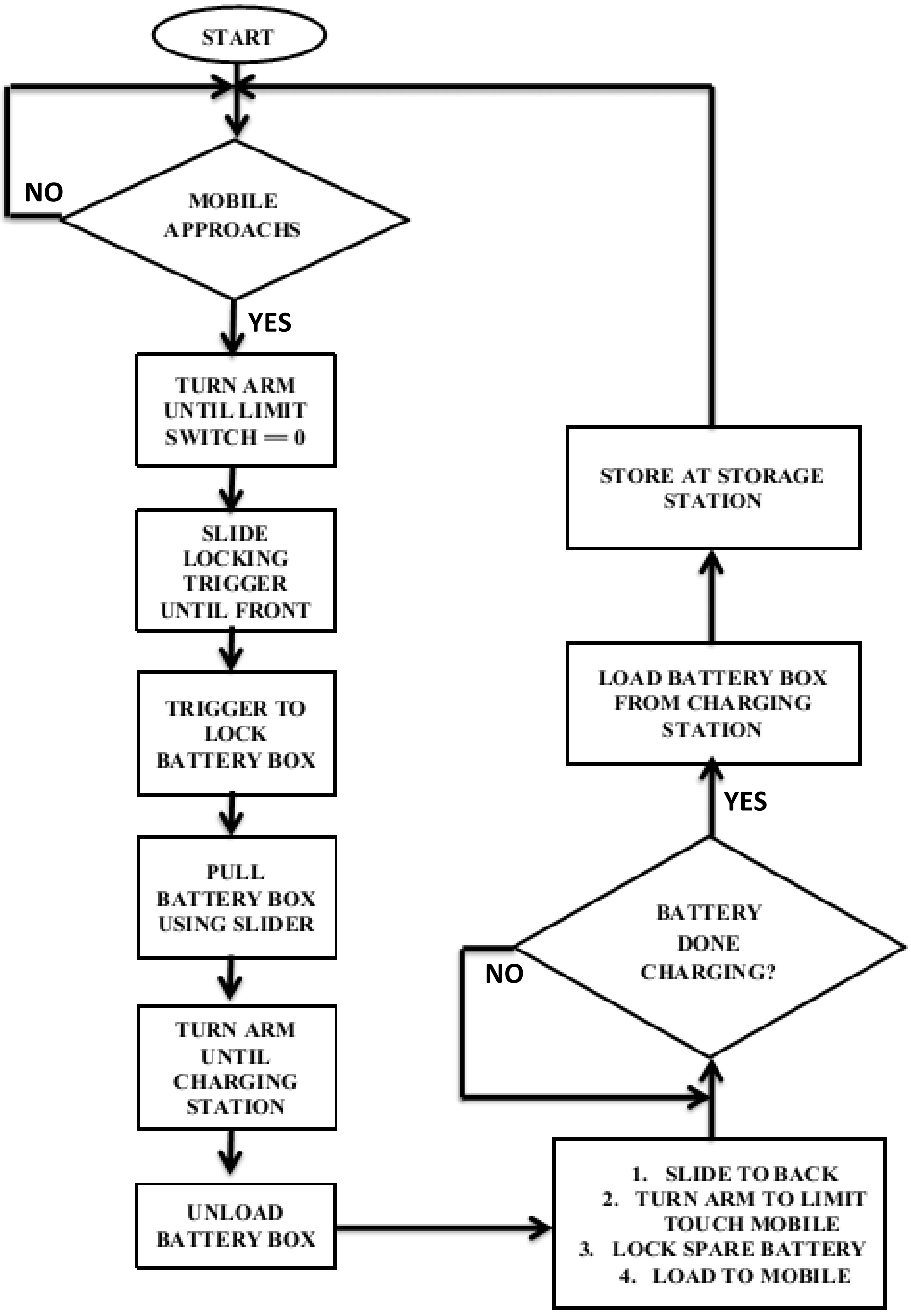


Figure 3.23 Process' flow at charger dock

CHAPTER 4

RESULT AND DISCUSSION

4.1 Hardware

Based on the problem statement and three main objectives discussed in Chapter 1, two mechanisms had been constructed. There are mobile robot and charger dock.

4.1.1 Mobile Robot

The mobile robot is use to transfer pallet from one station to another station. This mobile robot is drive by two DC brushless motor (BLH Series Brushless motor) with 4 pair of IR sensor circuit as a sensor to guide this robot to move by following the line. Four IR receivers were put at the base robot for detecting the charger dock. Figure 4.1 shows the isometric view of the actual form of mobile robot.

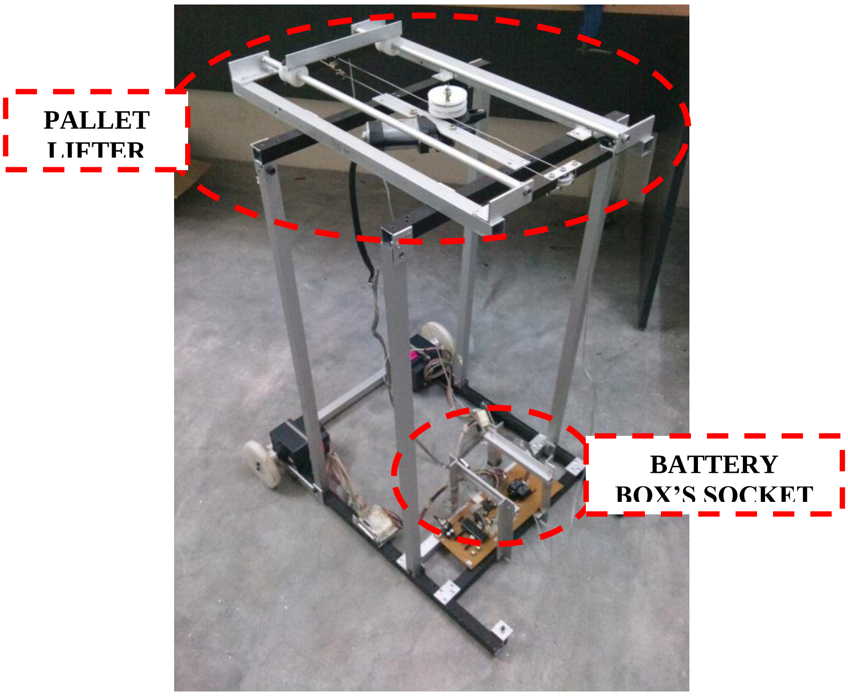


Figure 4.1 Mobile robot

4.1.2 Charger Dock

At first, charger dock is design as shown in Figure 3.3 in Chapter 3. The actual form is shown in Figure 4.2. It uses 3 motors to actuate all mechanism part; 2 power windows and 1 RC servo motor. A power window is used to rotate the arm and the other power window is used to slide the locking trigger.

But, the position of power window which is used to slide locking trigger is not suitable. It is locate at the end of the arm which produces large amount of inertia when the arm is rotated. In addition, the power window itself is heavy. This will result the charger dock not stable when the arm is rotating.

The solution is to exchange the power window with lighter motor and the position of the motor is change to the center of the arm. For this purpose, a DC geared motor; model SPG30-30 is used. The new of the charger dock design is shown is Figure 4.3.

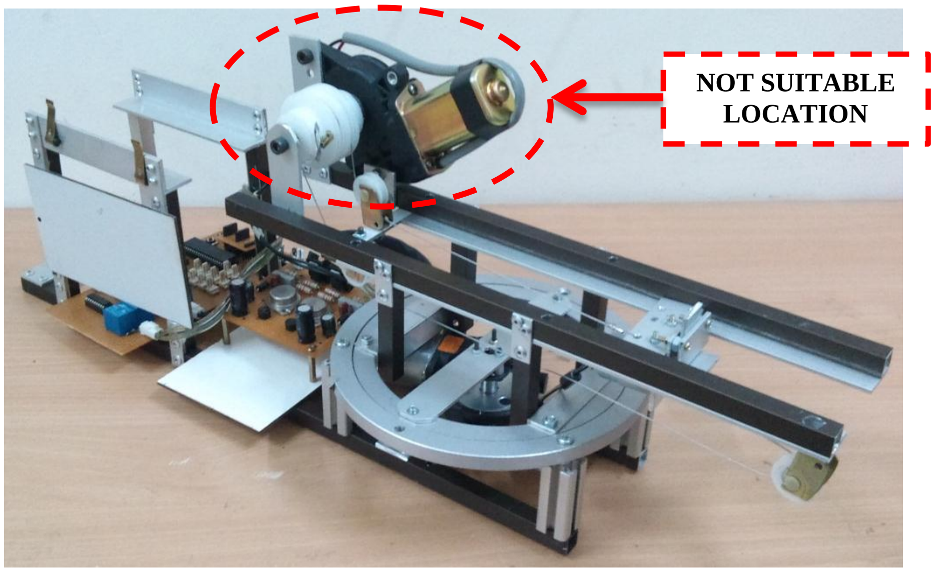


Figure 4.2 First version of charger dock

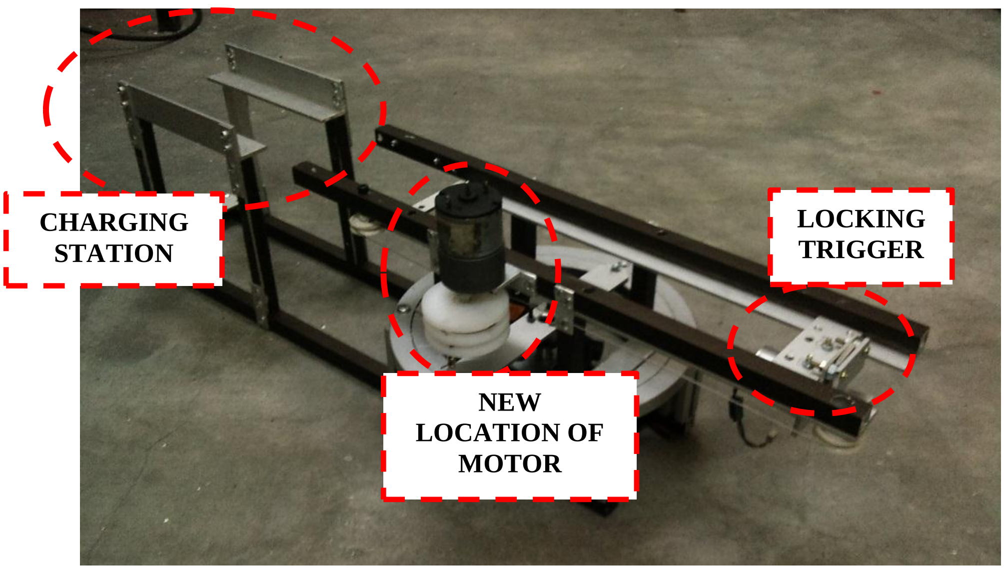


Figure 4.3 Second version of charger dock

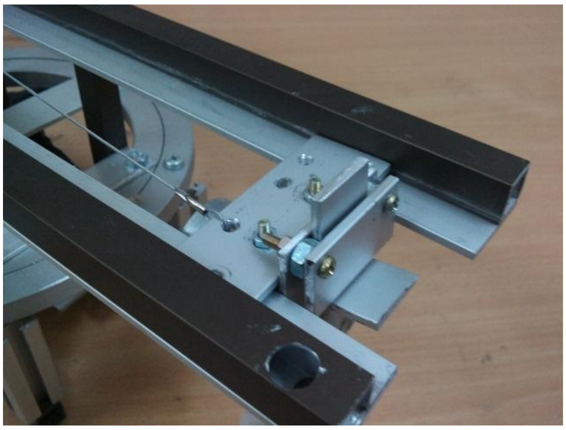


Figure 4.4 Locking trigger

4.1.3 Battery Box

This battery box (Figure 4.4) can store 2 SLA 12V Battery. Two copper plates at its side are connected to the battery terminal. The purpose of using this copper plate is to make the process attach and detach to its socket become easier, which is the battery box only need to slide to the limit of the socket to connect the battery to the circuit.

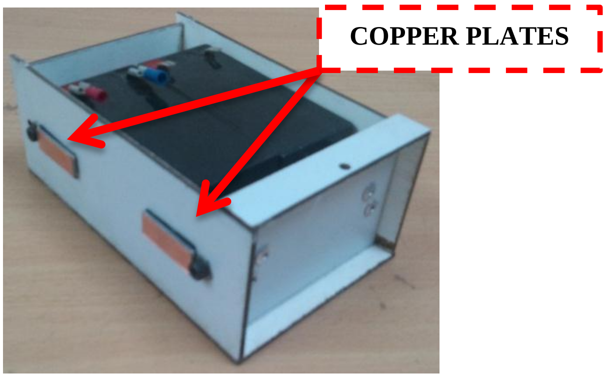


Figure 4.5 Battery box

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

For the conclusion, there 3 main parts that have been construct in this project; mechanism, electronic and programming. In mechanism part, there are 3 products which is mobile robot, charger dock and battery box. Practically, this project is suitable for pallet lifting application that transfer pallet from one station to another. The mechanism at the mobile robot has auto detect pallet feature which is it will wait for pallet presence. Using this system will eliminate human work to change the mobile robot battery and time of maintenance can be reduced; instead go and charge, it is better to go and replace its battery which is it can the time.

5.2 Recommendation

For future plan, it is advisable to upgrade some part of this project such as listed below:

1. To add power saver mode which is can extend battery life. This feature can be upgrade by upgrading in circuit part.
2. Enhancing communication system between mobile robot and charger dock as infrared beam can be blocked by an obstacle.

REFERENCES

C. Riccardo, T. Fabio, B. Paolo and F. Roberto. *Docking and Charging System for Autonomous Mobile Robots.* University of Brescia; 2005.

Cytron Technologies. *USB ICSP PIC Programmer User's Manual V1.0.* Malaysia: Product User's Manual. December 2011.

E. Maningat, B. Monterola, E. Obrero, R. Samante, and J. Villafuerte. *Random Walk Application for Autonomous Vacuum Cleaner Robot.* Ateneo de Naga University.

http://img.diytrade.com/cdimg/950543/9661382/0/1247100999/DC_Motor_Suitable_for_Toys_and_Garden_Tools.jpg as viewed on June 2012

http://www.cytron.com.my/viewProduct.php?pcode=HD-1160A&name=RC%20Micro%20Servo%20Motor as viewed on May 2012

http://www.cytron.com.my/viewProduct.php?pcode=MO-PW-R as viewed on May 2012

http://www.engineersedge.com/motors/brushless_dc_motor.htm as viewed on June 2012

http://www.gadgetfolder.com/super-efficient-rfid-tag-reader-from-mitsubishi.html as viewed on November 2011

http://www.industrysearch.com.au/Products/Handheld-RFID-Reader-Intermec-IP30-64353 as viewed on November 2011

http://www.interinar.com/vexta-pk244-02ba-c5.html as viewed on June 2012

http://www.orientalmotor.com/products/brushless-motors/blh-series.html as viewed on June 2012

http://www.schursastrophotography.com/robotics/dockinglogic.html as viewed on November 2011

L. Dazhai, F Hualei, and W. Wei. Ultrasonic Based Autonomous Docking on Plane for Mobile Robot. *Proceeding of the IEEE International Conference on Automation and Logistics.* September, 2008. Qingdao, China: IEEE, 2008. 1396-1401.

M. C. Silverman, B. Jung, D. Nies and G. S. Sukhatme. *Staying Alive Longer: Autonomous Robot Recharging Put to the Test.* University of Southern California; 2003.

Microchip Technology Inc. *dsPIC30F Family Reference Manual*. U.S.A: Datasheet. 2003.

National Semiconductor Corporation. *LM138/LM338 5-Amp Adjustable Regulators.* Product Specification. May 1998

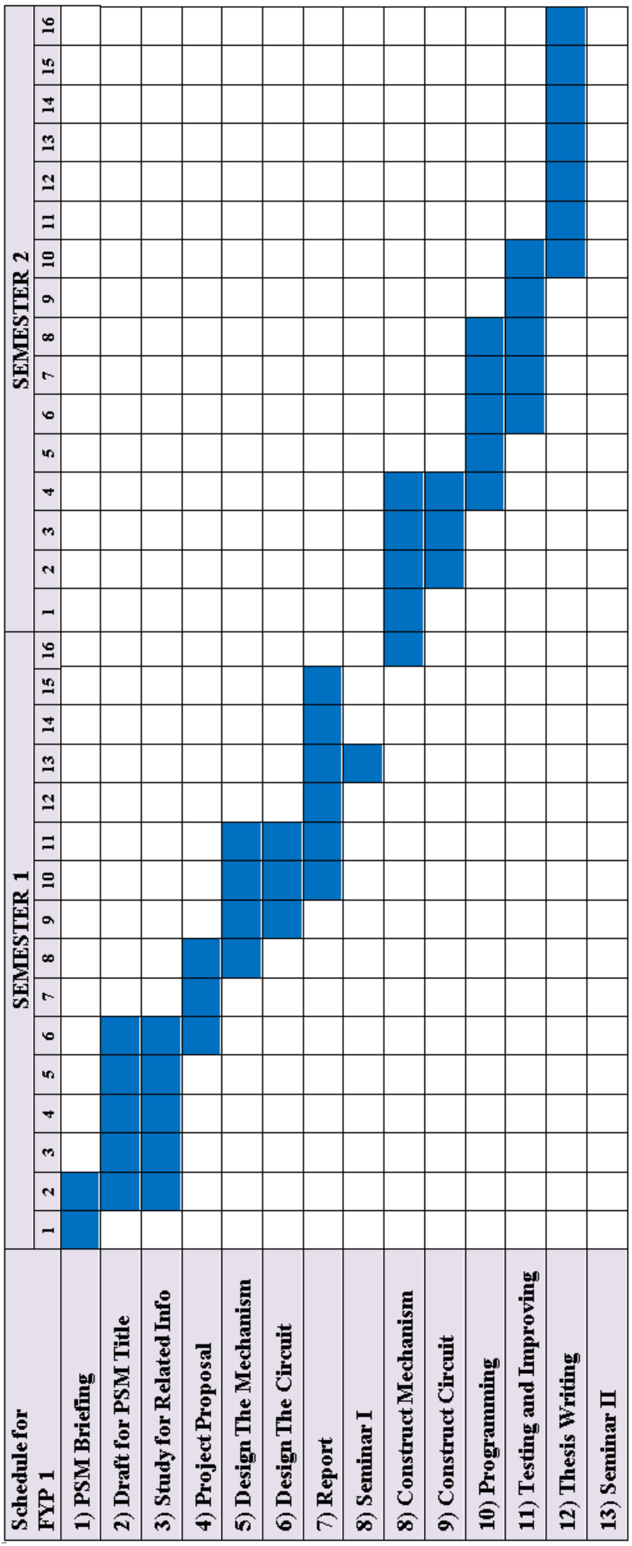
O. Diegel, J. Potgieter, and T. Cao. Where Waldo? Low Cost RF Indoor Tracking Systems. *1st International Conference on Sensing Technology.* November 21-23, 2005. Palmerston North, New Zealand: 2005. 48-53.

P. Arena, S. De Fiore, L. Fortuna, L. Nicolosi, L Patan´ e, and G. Vagliasindi. Visual Homing: Experimental Results on an Autonomous Robot. *IEEE 2007.* 2007. Catania, Italy: IEEE. 2007. 304-307.

Philips Semiconductors. *Low Power Quad Op Amps.* Product Specification. November 1995.

APPENDIX A

GANTT CHART FOR THE PROJECT



APPENDIX B
PROGRAMMING CODE FOR MOBILE ROBOT

```
#include <p30f4011.h>

_FOSC(CSW_FSCM_OFF & XT_PLL8);
_FBORPOR(MCLR_EN & PWRT_OFF);



//Define Input & Output

#definebutton1          _RD1
#definebutton2          _RD3
#defineled1       _LATC13
#defineled2       _LATC14
#defineled3       _LATE8

#define Rccw      _LATB0
#define Rrun      _LATB1
#define Rspeed          PDC1
#define Lccw      _LATB2
#define Lrun      _LATB3
#define Lspeed          PDC2
#define pwindow1  _LATB4
#define pwindow2  _LATB5
#define pw_speed  PDC3

#define z_1             _RE5
#define s0_1      _LATF0
#define s1_1      _LATF1
#define s2_1      _LATF4
#define z_2             _RF5
#define s0_2      _LATF6
#define s1_2      _LATD0
```

```
#define s2_2              _LATD2

//Define Pin for Multiplexer

#defineIRdock_L       mux_1(0)
#defineIRdock_R       mux_1(1)
#defineIRdock_FL      mux_1(2)
#defineIRdock_RL      mux_1(3)
#definesensor0                    mux_1(4)
#definesensor1                    mux_1(5)
#definesensor2                    mux_1(6)
#definesensor3                    mux_1(7)
#definebattery            mux_2(2)
#definepallet             mux_2(5)
#defineunload             mux_2(1)
#defineload               mux_2(6)
#definel_dock             mux_2(0)
#definer_dock             mux_2(7)
#define batterydock   mux_2(3)

//Global Variable

unsigned char mode;
unsigned char memLine;
unsigned char junction;
unsigned short mux;

unsigned char mux_1(unsigned char w);
unsigned char mux_2(unsigned char w);

//Funtion Prototype

void stop (void);
void turn (void);
```

```
void forward (void);
void reverse (void);
void turn_180 (void);
void turn_left (void);
void turn_right (void);
void pw_stop (void);
void pw_forward (void);
void pw_reverse (void);
void un_loadPallet (void);
void line_following (void);

void delay (unsigned long i);
void execute (unsigned char task);
void indicator (unsigned char show);
void count_junction (unsigned char bil);

void __attribute__((__interrupt__,auto_psv)) _OscillatorFail(void)
{       while(1){;}     }
void __attribute__((__interrupt__,auto_psv)) _AddressError(void)
{       while(1){;}     }
void __attribute__((__interrupt__,auto_psv)) _StackError(void)
{       while(1){;}     }
void __attribute__((__interrupt__,auto_psv)) _MathError(void)
{       while(1){;}     }
void __attribute__((__interrupt__,auto_psv)) _T3Interrupt(void)
{
        _T3IF = 0;                                      //clear flags

        if (battery == 1)
        {
                if (IRdock_R == 1 && IRdock_L == 0)
                {
                        memLine = 1;
                        while (IRdock_L == 0 || IRdock_R == 0)
```

```
    {
        turn_right();
    }

    while ( (l_dock == 0) || (r_dock == 0) )
    {
        forward();
    }

    stop();
    delay(850);
}

else if (IRdock_R == 0 && IRdock_L == 1)
{
    memLine = 2;
    while (IRdock_L == 0 || IRdock_R == 0)
    {
        turn_left();
    }

    while ( (l_dock  == 0) || (r_dock == 0) )
    {
        forward();
    }

    stop();
    delay(850);
}

while (batterydock == 0){;}
reverse ();
delay (10000);
turn_left();
```

```
            delay(2700000);
            while( (sensor0 == 1) || (sensor3 == 1) )
            {
                  forward();
            }
      }
}

//Initialization for Microcontroller

void init(void)
{
      ADPCFG = 0xfffe;     //define input output for pin
      TRISB =0x0000;
      TRISC =0x0000;
      TRISD =0x000a;
      TRISE =0x0020;
      TRISF =0x0020;

      OC1CON = 0x0000;   //close all OCxCON
      OC2CON = 0x0000;
      OC3CON = 0x0000;
      OC4CON = 0x0000;
      IC1CON = 0x0000;    //close all ICxCON
      IC2CON = 0x0000;
      IC7CON = 0x0000;
      IC8CON = 0x0000;

      PTCONbits.PTEN=1;
      PWMCON1    = 0x0F03;
      PTCON = 0x2003;             //1:1 prescale and postscale, up/down double
updates
      PTMR = 0x0000;
      PTPER = 511;          //10-bit resolution, 29.296875KHz PWM
```

```
	SEVTCMP = 0x0000;
	PWMCON2 = 0x0004;		//immediate PDC updates
	FLTACON = 0x0000; //disable Fault A control
	OVDCON = 0xff00;	//disable override control
	PDC1 = PDC2 = 0;	//initial duty cycle equals zero, 1024 equals 100%

	T3CON=0x2010;			//set Timer 3 synchronize with internal clock,
1:8 prescale
	PR3=375;			//interrupt every 0.1ms (formula =
2ms/((1/30M)x 64) )
	TMR3=0;

	SRbits.IPL	= 7;	// disable all user's interrupt
	INTCON1		= 0x0000;
	INTCON2		= 0x0000;
	IFS0 = 0x0000;
	IFS1 = 0x0000;
	IFS2 = 0x0000;			// clear all interrupt flag

	SRbits.IPL	= 0;	// disable all user's interrupt
	_T3IE = 1;			//enable Timer 3 interrupt
	_T3IP = 4;			//T3 low pirority



	U2STAbits.UTXEN =1;		//enable transmit
}

//Main Program

int main()
{
	init();
	T3CONbits.TON=1;
	mode = 0;
```

```
        indicator(0);
        while(1)
        {
                while (pallet == 1){;}          //no pallet in front
                un_loadPallet();
                turn_180();
                count_junction (1);
                turn_left();
                count_junction(1);
                turn_left();
                forward();
                delay(100000);

                un_loadPallet();
                turn_180();
                count_junction (1);
                turn_right();
                count_junction(1);
                turn_right();
                forward();
                delay(100000);
        }
}

void delay (unsigned long i)
{
        for (   ; i>0 ;  i--       );
}

//              INDICATOR & SWITCH MODE

void indicator (unsigned char show)
{
        switch(show)
```

```
	{
		case 0 :led1=1; led2=1; led3=1; break;
		case 1 :led1=1; led2=1; led3=0; break;
		case 2 :led1=1; led2=0; led3=1; break;

		case 3 :led1=1; led2=0; led3=0; break;
		case 4 :led1=0; led2=1; led3=1; break;

		case 5 :led1=0; led2=1; led3=0; break;
		case 6 :led1=0; led2=0; led3=1; break;
		case 7 :led1=0; led2=0; led3=0; break;

	}
}

void execute (unsigned char task)
{
	switch(task)
	{
		case 0 :led1=1; led2=1; led3=1; delay(2727272/2);
				led1=0; led2=0; led3=0; delay(2727272/2);
				break;
		case 1 :led1=1; led2=1; led3=0; delay(2727272/2);
				led1=1; led2=1; led3=1; delay(2727272/2);
				break;
		case 2 :led1=1; led2=0; led3=1; delay(2727272/2);
				led1=1; led2=1; led3=1; delay(2727272/2);
				break;
		case 3 :led1=1; led2=0; led3=0; delay(2727272/2);
				led1=1; led2=1; led3=1; delay(2727272/2);
				break;
		case 4 :led1=0; led2=1; led3=1; delay(2727272/2);
				led1=1; led2=1; led3=1; delay(2727272/2);
				break;
```

```
                case 5 :led1=0; led2=1; led3=0; delay(2727272/2);
                        led1=1; led2=1; led3=1; delay(2727272/2);
                        break;
                case 6 :led1=0; led2=0; led3=1; delay(2727272/2);
                        led1=1; led2=1; led3=1; delay(2727272/2);
                        break;
                case 7 :led1=0; led2=0; led3=0; break;

        }
}

//              POWER WINDOW

void un_loadPallet (void)
{
        while (unload == 1)
        {
                pw_forward();
        }
        pw_stop();
        delay(850);

        while (load == 1)
        {
                pw_reverse();
        }

        pw_stop();
        delay(850);
}

void pw_forward (void)
{
        pwindow1 = 1;
```

```
        pwindow2 = 0;
}

void pw_reverse (void)
{
        pwindow1 = 0;
        pwindow2 = 1;
}

void pw_stop (void)
{
        pwindow1 = 0;
        pwindow2 = 0;
}

//              VEXTA

void forward (void)
{
        Lrun=Rrun=0;
        Lccw=0;
        Rccw=1;
}

void stop (void)
{
        Lrun=Rrun=1;
        Lspeed=Rspeed=0;
        delay(10000);
}

void reverse (void)
{
        Lrun=Rrun=0;
```

```
        Lccw=1;
        Rccw=0;
}

void count_junction (unsigned char bil)
{
        junction = 0;
        while (junction < bil)
        {
                line_following();
                if( !sensor0 && !sensor3 )
                {
                        junction++;
                }
        }
}

void turn_right(void)
{
        Lrun = Rrun = 0;
        Lccw = 1;
        Rccw = 1;
        Lspeed = Rspeed = 100;
}

void turn_left(void)
{
        Lrun = Rrun = 0;
        Lccw = 0;
        Rccw = 0;
        Lspeed = Rspeed = 100;
}

void turn_180 (void)
```

```
{
	while ( !sensor0 || !sensor1 || !sensor2 || !sensor3 )
	{
		turn_right();
	}

	stop();
	delay(850);

	while ( (sensor1 == 1) || (sensor2 == 1))
	{
		turn_right();
	}

	stop();
	delay(850);
}

//		LINE FOLLOWING

void line_following (void)
{
	unsigned char position = 0b0000;

	if(sensor0 == 0)	{ position += 0b1000; }
	else if(sensor1 == 0)	{ position += 0b0100; }
	else if(sensor2 == 0)	{ position += 0b0010; }
	else if(sensor3 == 0)	{ position += 0b0001; }

	switch(position)
	{
		case 0b1000	:	forward();
						memLine = 1;
						Rspeed = 100;
```

```
                        Lspeed = 150;
                        break;

case 0b0100   :   forward();
                        memLine=1;
                        Rspeed = 100;
                        Lspeed = 150;
                        break;

case 0b1100   :   forward();
                        memLine = 1;
                        Rspeed = 100;
                        Lspeed = 150;
                        break;

case 0b0110   :   forward();
                        Rspeed = 150;
                        Lspeed = 150;
                        break;

case 0b0011   :   forward();
                        memLine = 2;
                        Rspeed = 150;
                        Lspeed = 100;
                        break;

case 0b0010   :   forward();
                        memLine = 2;
                        Rspeed = 150;
                        Lspeed = 100;
                        break;


case 0b0001   :   forward();
```

```
                    memLine = 2;
                    Rspeed = 150;
                    Lspeed = 100;
                    break;

case 0b0000 :  if(memLine == 1)
                {
                    delay(100000);
                    while(sensor3 == 0)
                    {
                        turn_left();
                    }
                    stop();
                }

                else if(memLine == 2)
                {
                    stop();
                    delay(100000);
                    while(sensor0 == 0)
                    {
                        turn_right();
                    }
                    stop();

                }

                break;

default        :    forward();
                        Rspeed = 150;
                        Lspeed = 150;
                        break;
```

```
    }
}

//          MULTIPLEXER

unsigned char mux_1(unsigned char w)
{
    s0_1 = (w&0b0001)?1:0;
    s1_1 = (w&0b0010)?1:0;
    s2_1 = (w&0b0100)?1:0;

    delay(100);
    if(z_1==0) {return 0;}
    else if(z_1==1) {return 1;}
}

unsigned char mux_2(unsigned char a)
{
    s0_2 = (a&0b0001)?1:0;
    s1_2 = (a&0b0010)?1:0;
    s2_2 = (a&0b0100)?1:0;

    delay(100);
    if(z_2==0) {return 0;}
    else if(z_2==1) {return 1;}
}
```